RESOURCE ALLOCATION SCHEME FOR FUTURE USER-CENTRIC WIRELESS NETWORK

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RESOURCE ALLOCATION SCHEME FOR FUTURE USER-CENTRIC
WIRELESS NETWORK

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
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Dedicated to my beloved parents, supervisor, seniors and friends.

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ABSTRACT

Current communication landscape focuses on the integration of networks, where these networks exhibit heterogeneous characteristics. The motivation for such network integration arises the advent of the smart end-user devices and revolutionary advances in other network components, the telecommunication business models shift focus from network-centric to the user-centric paradigm. This further dictates that operators will find the profit windows in increasing the satisfied user pool, which intuitively may be translated into meeting the user requirements. The shift towards new paradigm gives birth to several major issues and suitability of the current bandwidth sharing algorithms is one of them. The research work for the new paradigm is confined to inter operator and intra operator levels only. The bandwidth allocation at last mile, i.e. at user-end is not widely addressed. There is a need for an optimal solution that considers user perceived Quality of Experience (QoE) in bandwidth allocation at user-end. An optimal solution of this problem will maximize user satisfaction and increase operator's revenue. Adapting the economic components of the existing user satisfaction function will capture the user behaviour more realistically against multiple parameters. A user perceived QoE-based distributed decision making algorithm at network level will be deployed at base station and the interdependency would be captured. The characteristics of involved access technologies i.e. (WLAN, UMTS) will be confined to capacity and coverage only. MATLAB implementation is used to proof the concept. The performance gain of the proposed work was investigated by using various performance evaluation criteria, such as call blocking probability, operator's revenue maximization and user satisfaction. The proposed optimum bandwidth allocation algorithm is compared with non-optimum bandwidth allocation algorithm in single radio interface as well as in heterogeneous environment. The obtained results show that optimum bandwidth allocation model maximizes user satisfaction and operator's revenue and minimizes number of calls rejection.

ABSTRAK

Landskap komunikasi semasa memberi tumpuan kepada integrasi rangkaian, di mana rangkaian ini mempamerkan ciri-ciri yang berbeza. Motivasi bagi integrasi rangkaian sebegini berpunca daripada kemunculan peranti pengguna akhir pintar dan kemajuan dalam komponen rangkaian yang lain, model perniagaan telekomunikasi mengalihkan fokus kepada paradigma rangkaian berteraskan pengguna. Ini seterusnya menetapkan bahawa pengendali akan mendapati keuntungan dalam meningkatkan bilangan pengguna yang berpuas hati yang secara intuitif boleh diterjemahkan ke dalam memenuhi keperluan pengguna. Perubahan ke arah paradigma baru melahirkan beberapa isu utama dan kebolehgunaan algoritma perkongsian jalur lebar semasa adalah salah satu daripada isu-isu tersebut. Kerja-kerja penyelidikan bagi paradigma baru ini adalah terbatas hanya kepada antara operator dan intra operator. Peruntukan jalur lebar pada sambungan akhir, iaitu pada pengguna akhir tidak ditangani secara meluas. Satu penyelesaian optimum yang mengambil kira Kualiti Pengalaman (QoE) diperlukan untuk peruntukan jalur lebar pada perspektif pengguna akhir. Penyelesaian optimum masalah ini akan memaksimumkan kepuasan pengguna dan meningkatkan keuntungan pengendali. Menyesuaikan komponen ekonomi untuk fungsi kepuasan pengguna yang sedia ada akan merekod perilaku pengguna yang lebih realistik terhadap pelbagai parameter. Algoritma untuk membuat keputusan berasaskan QoE di peringkat rangkaian akan digunakan di stesen pengkalan dan hubungan antara proses ini direkod. Ciri-ciri teknologi akses yang terlibat (iaitu WLAN dan UMTS) adalah terhad kepada kapasiti dan liputan sahaja. Model ini diimplementasi dengan MATLAB untuk membuktikan konsep. Peningkatan prestasi untuk kerja yang dicadangkan telah disiasat dengan menggunakan pelbagai kriteria penilaian prestasi, seperti penyekatan panggilan, memaksimumkan hasil pendapatan pengendali dan kepuasan pengguna. Algoritma jalur lebar optimum yang dicadangkan dibandingkan dengan algoritma jalur lebar bukan optimum dalam radio antara muka tunggal dan dalam persekitaran pelbagai. Keputusan menunjukkan model pembahagian jalur lebar optimum berupaya memaksimakan kepuasan pengguna dan pendapatan operator dan meminimumkan jumlah pangglian yang ditolak.

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LIST OF ABBREVIATIONS

3G	–	3rd Generation
4G	–	Fourth Generation
ANDSF	–	Access Network Discovery and Selection Function
AHP	–	Analytical Hierarchy Process
ACR	–	Absolute Category Rating
AP	–	Access Point
ABC	–	Always Best Connection
BS	–	Base Station
BTS	–	Base Transceiver Station
CBR	–	Constant Bit Rate
CCK	–	Complementary Code Keying
CDMA	–	Code Division Multiple Access
CDF	–	Cumulative Density Function
CN	–	Core Network
DBPSK	–	Differential Binary Phase Shift Keying
DQPSK	–	Differential Quadrature Phase Shift Keying
DSSS	–	Direct Sequence Spread Spectrum
FHSS	–	Frequency Hopping Spread Spectrum
FDD	–	Frequency Division Duplexing
FTP	–	File Transfer Protocol
GPRS	–	General Packet Radio Service
GSM	–	Global system for Mobile Communication
GGSN	–	Gateway GPRS Support Node
IP	–	Internet Protocol
IrDA	–	Infrared Data Association
IWU	–	inter-working unit
ISDN	–	Integrated Services Digital Network
IMS	–	IP (Internet Protocol) Multimedia Subsystem

JCAC	–	Joint Call Admission Control
LAN	–	Local Area Network
MT	–	Mobile Terminal
MS	–	Mobile Station
MN	–	Mobile Node
MAUT	–	Multi-Attribute Utility Theory
MOS	–	Mean Opinion Score
MNB	–	(Measuring Normalizing Blocks
Node-Bs	–	UMTS Base Stations
NRT	–	Non-Real Time
OSI	–	Open System Interconnection
OFDM	–	Orthogonal Frequency Division Multiplexing
PS	–	Packet Switched
PSQM	–	Perceptual Speech Quality Measure
PESQ	–	Perceptual Evaluation of Speech Quality
QoE	–	Quality of Experience
QoS	–	Quality of Service
RNSs	–	Radio Network Subsystems
RNCs	–	Radio Network Controllers
RANS	–	Radio Access Network Station
RAN	–	Radio Access Network
RAN	–	Radio Access Network
RT	–	Real Time
RAT	–	Radio Access Technology
RATs	–	Radio Access Technologies
RSS	–	Received Signal Strength
SMART	–	Smart Multi-Attribute Rating Technique
SGSN	–	Serving GPRS Support Node
SRNS	–	Serving Radio Network System
SDF	–	Satisfaction Degree Function
TDD	–	Time Division Duplexing
UMTS	–	Universal Mobile Telecommunications System
UE	–	User Equipment
UTRAN	–	UMTS Terrestrial Radio Access Network
VBR	–	Variable Bit Rate

WCDMA	–	Wide-band Code Division Multiplexing
WLAN	–	Wireless Local Area Network
WMAN	–	Wireless Metropolitan Area Network
WLAN	–	Wireless Local Area Network

LIST OF SYMBOLS

γ_{n_k}	–	Amount of bandwidth allocated to *n* number of users of type *k*
l_γ	–	Lower bound of the variable γ
u_γ	–	Upper bound of variable γ
B_t	–	Current bandwidth capacity of network technology
β	–	A parameter that controls to sensitivity of allocated bandwidth
$Q(\gamma_{n_k})$	–	Sum of unit resource cost incurred by network technology
$B_\omega^\alpha(x)$	–	Vector of total allocated bandwidth by network ω in coverage area α *k* type of a user ,i.e. Excellent, Good, Fair
γ_{min}	–	Minimum bandwidth allocation limit
γ_{max}	–	Maximum bandwidth allocation limit
$P(\gamma_{n_k})$	–	Network profit against allocated bandwidth γ to *n* number of users of type *k*
π	–	Resource revenue attained from service consumer
μ	–	Maximum user utility threshold
U_ω	–	Utility of RAN ω
C_j	–	Capacity of network *j*
O_j	–	Coverage area of network *j*
μ_0	–	User private valuation

CHAPTER 1

INTRODUCTION

1.1 Future Wireless Paradigm

Current communication landscape focuses on the integration of networks, where these networks exhibit heterogeneous characteristics. Due to advent of the smart end-user devices and revolutionary advances in other network components, the telecommunication business models shift focus from network-centric to the user-centric paradigm. This business model dictates that operators should maximize satisfied user pool, which intuitively may be translated into meeting the user requirements, in order to increase their profits [2, 5, 7, 8]. On the other hand, a single network access technology may not be able to cope with the bandwidth hungry applications of the future. This forms the basis for convergence of heterogeneous wireless access technologies [9,10]. This convergence gives birth to a resource sharing dilemma.

1.1.1 Resource Sharing Dilemma

Integrated technologies are based on differentiation of multiple parameters such as medium access, network capacity, network coverage, physical resources, core network and radio network [3]. To further elaborate the resource sharing dilemma, Table 1.1 highlights the parameters on which one technology is differentiated from another. These diverse technologies create a big challenge for a network operator to share resources efficiently.

1.2 Background on User Centric Paradigm

Current practices in the telecommunication business still tie the users to a single operator even though there are many operators in the market. The users tend to manually combine their subscriptions to multiple operators in order to take advantage of different offers that are suited for a variety of services.

Table 1.1: An overview of the mobile communication evolution [1]

Gen	Technology	Frequency	Throughput	Coverage	Muxing
2G	GSM/TDMA	200KHz	14.4Kbps	35km	TDMA/ CDMA
2.5G	GSM/GPRS	800MHz (Europe) 1900MHz (US)	14.4Kbps	35km	TDMA/ CDMA
3G	UMTS/WCDMA	15 MHz - 20MHz	2Mbps	2km	CDMA
4G	LTE/WiMAX	$>$ 100MHz	200Mbps	10km	CDMA/ OFDMA
BB	WLAN	2.4GHz - 5GHz	(54,11,600)Mbps	100m	OFDM/ DSSS

For example, a user might hold two SIM cards/phones from two different operators, one of which provides a flat-rate national calling plan while the other provides low cost, high-quality international calling with pay-as-you-go option. Extending this example to a case where there are a large number of operators with a multitude of service options and offers in future all-IP telecommunication networks, manual handling of such multi-operator service combinations is clearly tedious and impractical for the user [3].

In its most generic sense, the user-centric view in telecommunications considers that the users are free from subscription to any one network operator and can instead dynamically choose the most suitable transport infrastructure from the available network providers for their terminal and application requirements. In this approach, the decision of interface selection is delegated to the mobile terminal enabling end users to exploit the best available characteristics of different network technologies and network providers, with the objective of increased satisfaction [3].

In user-centric networking paradigm for future telecommunication networks, the users not only make network-selection decisions based on their local Quality of Experience (QoE) evaluation but also share their QoE evaluations with each other for increased efficiency and accuracy in network selection, as depicted in Figure 1.1 [3].

1.3 Statement of The Study

In user-centric paradigm, the users will have short term contracts with the operators and utilizes much smaller time quanta each time the users use the network [2, 7, 9–12] Therefore the applicability of current bandwidth allocation algorithms for the new envisioned paradigm is a big question. Researchers have suggested a lot of good works on bandwidth allocation dilemma in user-centric paradigm [2,9,11,13,14]. However, these algorithms are confined to inter-operator and intra-operator levels only. The bandwidth allocation at last mile, i.e. at user end is not widely addressed. There is a need for an optimal solution that considers user perceived QoE in bandwidth allocation at last mile in downlink. An optimal solution of this problem will definitely maximize user satisfaction and increase operator's revenue at the same time.

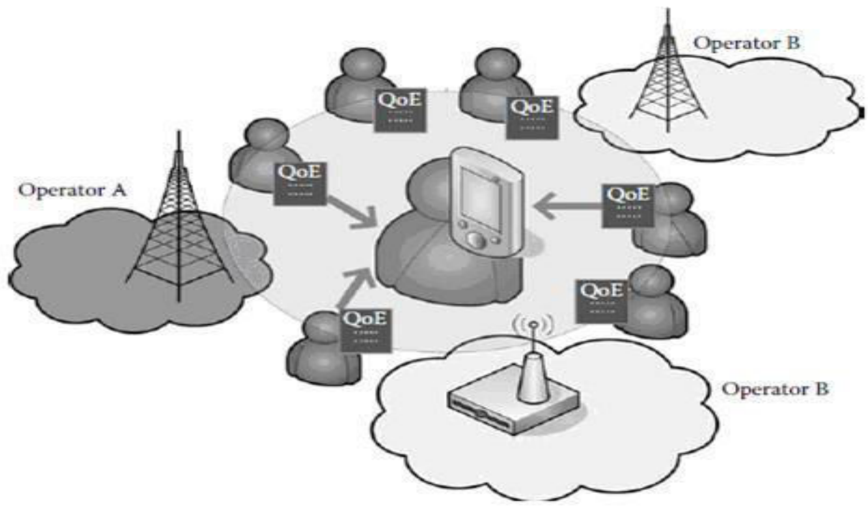

Figure 1.1: Sharing of QoE in user-centric network [3]

1.4 Research Objectives

The research work focuses on the envisioned user-centric telecommunication paradigm, which will influence operators to enhance their profit windows by increasing the satisfied user pool. The aforementioned facts motivate us to carry out the research on modeling the decision instances of resource allocation decisions at the network technology level. In order to achieve the goal, the sub-objectives are as below

i. To adapt the existing user satisfaction function and add an economic component for the function in order to measure user satisfaction more realistically.

ii. To optimize the resource allocation (at last mile) by considering the modified user satisfaction function (i.e. user perceived QoE) for user-centric telecommunication paradigm.

1.5 Scope of Work

The scope of the work is confined to radio resource allocation decisions at network technology level by considering single radio interface and heterogeneous radio interface environment. The overall system for network operation is depicted in Figure 1.2. Where the interdependency of different parameters is captured to make resource allocation decision at network level. The algorithm considers user perceived QoE and it is deployed at base station. In this research, without loss of generality, we assume only two access technologies, i.e. Wireless Local Area Network (WLAN) and Universal Mobile Telecommunications System (UMTS). We solve the resource allocation problem that are formulated using MATLAB, by utilizing its linear programming optimization solver. The performance gain of the proposed work is investigated by using three performance evaluation criteria, which are call blocking probability, profit maximization and user satisfaction.

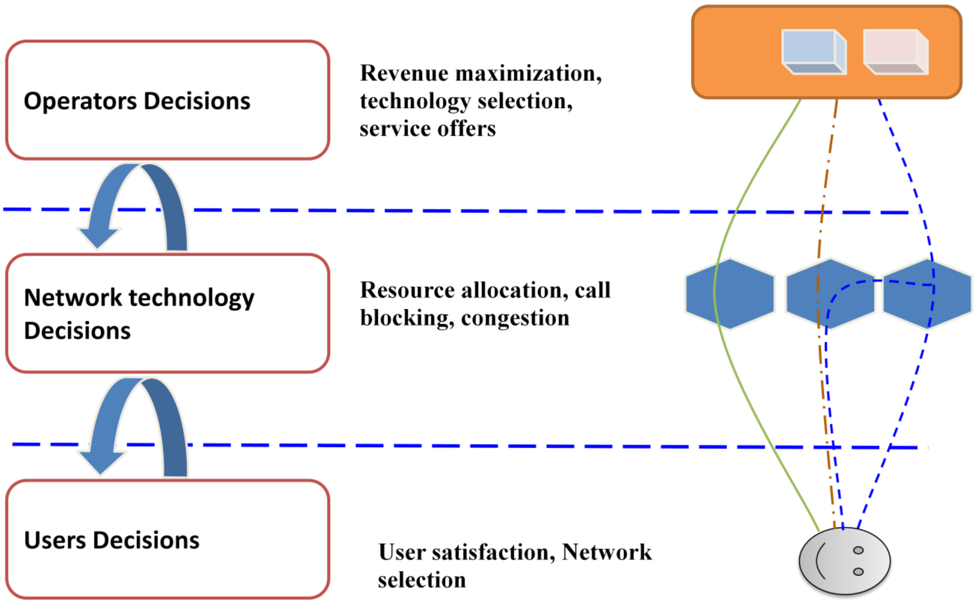

Figure 1.2: Overall network operation.

1.6 Research Contributions

We formulated a new resource allocation problem specifically for upcoming user-centric telecommunication infrastructure. We restrict our work only to bandwidth allocation. The problem, when solved, gives optimal bandwidth allocation to all, or majority of users, while minimizing call-blocking, achieves high user satisfaction levels, and maximizing operator profits at the same time. In the problem formulation, the user satisfaction function is made more realistic by adding a cost component.

1.7 Thesis Organization

This thesis is divided into seven chapters; introduction, literature review, research methodology, adapted user satisfaction function and front view of the model, standard bandwidth allocation model development, implementation of bandwidth allocation model and lastly the conclusion chapter.

The first chapter includes the introduction on future wireless network paradigm in which future user-centric environment is explained along with resource sharing issues, research background on user-centric paradigm, research objectives, limitations of the proposed system as well as the contributions of this research work.

Second chapter contains the theoretical background and critical reviews on current and prior works. The chapter contains introduction to UMTS cellular network and WLAN data network. The architecture of the two network technologies are briefly discussed along with introduction to interworking of these two network access technologies. Resource allocation approaches in heterogeneous and user-centric environment are reviewed in detail. We also discuss the QoE-based user satisfaction function.

Methodology applied for the formulation of the optimized resource utilization problem, as well as the description of optimization tools and mathematical model design for solving the optimization problem, are included in Chapter 3.

Chapter 4 is divided into two sections. First section describes adapted user satisfaction function, second section discusses front view of the model to help in understanding the whole concept of heterogeneous wireless resource sharing.

System model, bandwidth allocation model and standard bandwidth allocation model is covered in Chapter 5.

The sixth chapter describes the implementation procedures of the proposed mathematical model presented in Chapter 5. Experimental results and system performance analysis in terms of user satisfaction, call blocking probability and operator profit maximization are also discussed in Chapter 6.

The last chapter concludes the presented work and gives suggestions for future works.

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